Paper ID: 12461
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Exploration of Near Earth Asteroids (06)
Poster Session (P)

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LOW-COST GNC TECHNOLOGY FOR NEO EXPLORATION MISSIONS: APPLICATION TO MARCOPOLO-R AND OSIRIS-REX

Abstract

Asteroids offer great scientific opportunities. Exploration missions to small bodies, either sample return or in-situ observation, require advanced on-board technologies. One enabling technology is the Guidance, Navigation Control (GNC) system. The requirements of NEA missions on the GNC are very demanding. Cost is one of the main drivers for the design and development. Tight orbital and landing specifications are required for outstanding science objectives. Furthermore, robustness is critical because of the high uncertainty on most environment parameters. The GNC system developed by GMV is based on advanced algorithms fitting on existing flight processors, and low-cost, off-the-shelf sensors (wide-angle camera, radar altimeters, star-tracker) and actuators. The GNC system is tightly coupled with the operations timeline and the trajectory profile. An optimal share of on-board autonomy with ground operations allows for flexible, robust NEO missions with minimum development and operations cost. The on-board GNC provides support during the approach phase, from detection of the asteroid to insertion in a safe far station. In this approach phase, the GNC strategy permits the estimation of the complete state relative to the asteroid. This is not straightforward provided that there is not direct measurement of range. In addition refinement of asteroid properties during this phase is critical for the start of the proximity operations. During the proximity operations, the distance to the asteroid is decreased when knowledge of asteroid parameters is improved. Particularly interesting is a novel strategy to maintain safe distances without any altimeter (if using a radar altimeter with operational range below 5 km). In addition, the injection and maintenance on Self-Stabilised Terminator Orbits (aka Photo-Gravitational Orbits) is very interesting for global characterization and radio-science. Descent and Landing must be fully autonomous from a certain altitude (typically 500 m). Vision-based navigation and short range altimeters achieve required landing specifications and proper alignment wrt surface. Extensive testing of the GNC modes in high-fidelity simulator validates the system to TRL-4 (in 2011). The validation and verification considered the MarcoPolo sample-return scenarios. Application to MarcoPolo-R and Osiris-Rex demonstrate the capability of the GNC system (together with the approach and proximity operations profile) to adapt to different missions. MarcoPolo-R aims a binary asteroid, with landing accuracy 10 m (3-sigma) on the fast-rotating primary (3.5 h). In comparison, Osiris-Rex most demanding objectives are global mapping at 0.7-km distance and touch-and-go landing velocity of 0.1 m/s.